PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

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Monday, 17th December 1866.

The Hon. Lord NEAVES, Vice-President, in the Chair.

The following Communications were read:—

I. Influence of Marriage on the Death-Rates of Men and Women in Scotland. By James Stark, M.D., &c.

The object of this paper was to show the different death-rates which prevailed among the married and unmarried men and women in Scotland.

It was pointed out that the mortality among the unmarried men was, at all ages, very much higher than among the married; that, in fact, the mortality of the unmarried was thrice as high at the age 20 to 25 years; and only slowly approximated to that of the married man at 85 years of age.

The difference in the death-rates of the married and unmarried men was rendered more striking by calculating their mean age at death, when it was found that from 20 years to the close of life the mean age at death of the married man was 59½ years, that of the unmarried man only 40 years—giving a difference in favour of the married man of 19½ years of life. When the mean age at death was calculated from the 25th year, it was found to give a mean age of $60\frac{3}{10}$ths years to the married, but only $47\frac{7}{10}$ths years to the unmarried, or a difference of 12½ years in favour of married life.

It was pointed out that this appeared to be a special provision of nature to protect the father of a family, so that he might provide for his offspring, and superintend their rearing; but that it was also capable of being so far explained by natural causes. The married man was in one sense a selected life; because the weak, the diseased, the intemperate, and the licentious, did not marry; so that all this unhealthy class of persons remained bachelors, and it was a known fact that their mortality was high.

It was then pointed out that summarising the tables—that is, comparing the total deaths at all ages with the total number living, led to a conclusion the very opposite of the truth, inasmuch as it seemed to prove that unmarried men had the healthiest lives, for it showed that in every 100,000 unmarried men only 1723 died annually, in a like number of married men 2338 died; and the natural conclusion from such a fact would be, that the death-rate of the unmarried was much lower than that of the married man.

It was explained how this paradoxical result was produced; and the English Registrar-General's tables of the mortality of men following different occupations was referred to, showing the fallacy of summarising the facts in these tables, at the same time pointing out how the true comparative healthiness of each occupation could be ascertained.

The death-rates of the married and unmarried women were then explained. It was shown that at each quinquennial age, from 15 to 30 years, the death-rates of the married women slightly exceeded that of the unmarried, being greatest at the junior age, but approximating and becoming identical at 30. From 30 to 40 years the mortality of the married women was slightly lower than that of the unmarried, but from 40 to 45 it was very slightly higher. From 45 years to the close of life, however, the death-rates of the married women were lower than those of the unmarried. The difference, however, was comparatively trifling at every age, as compared with the mortality of the married and unmarried men.

It was explained that these variations in the death-rates of the married and unmarried women were explicable. The higher mortality among the married under 30 years was caused by the additional dangers which attended the birth of the first child, and just in proportion to the number of mothers who bore their first child was the mortality at each quinquennial period of life. The slightly higher mortality, again, in the married between 40 and 45 years of age, at which time the change of life occurs among the women of Scotland, was attributed to their constitutions having been somewhat weakened by this childbearing, lactation, and the extra labours and fatigues attending the rearing of their children.

2. On the Physiological Action of the Calabar Bean (*Physostigma venenosum*, Balf.) By Thomas R. Fraser, M.D.

Although many able observers have, within the last few years, investigated the physiological action of the Calabar bean, a singular amount of discordance has characterised the results arrived at. An intention, in the first place, of adding proofs in confirmation of the views advanced in an investigation published in 1862, has induced the author to reconsider the subject. The result has been that the actions of this substance have been found to be much more complicated than was at first supposed, and this may be understood when it is stated that it acts on the spinal cord and on the motor nerves, and also on the sympathetic system, and that, in this manner, it directly influences nearly all the vital functions. It is not proposed, at this time, to examine what must be regarded as the most curious action of Physostigma, that, namely, on the pupil, which results from its topical application to the eyeball or to the mucous membranes which are anatomically connected with it. The theories of this action, though some of them have been advanced by men of such eminence as Donders, Graefe, Rosenthal and Bowman, are extremely unsatisfactory. It is hoped that a distinct conception of the general physiological effects will suggest a correct explanation of the myositic action, and there can be no doubt it will assist in arriving at this conclusion.

In the following experiments, an extract prepared by acting on the finely pulverised kernel with boiling alcohol has been used. This preparation contains a considerable proportion of fatty matter, which prevents its perfect solution in water; and, as the division into separate doses of a mere watery suspension would lead to many inaccuracies, it was found necessary to weigh the requisite quantity of extract, separately, for each experiment. This extract is hygroscopic, which further required that it should be dried and kept *in vacuo* over sulphuric acid. The greatest number of the experiments were made with the common frog (*Rana temporaria*), birds, and various mammals. It was found that fatal results were produced with the smallest quantity on birds, and that the largest doses, in proportion to weight, were required by amphibia. A dose of one-sixteenth of a grain proved rapidly fatal to a pigeon, whereas three grains have been recovered from by a frog—a quantity sufficient to produce death in a dog of average size.

The immediate causes of death in birds and mammalia were found to be syncope and asphyxia, or a combination of the two; and a marked connection was observed between the dose and its rate of absorption, and the preponderance of one or other of these effects. In frogs, the cardiac and respiratory functions were rapidly affected, but complete destruction of all the vital functions of the animal never occurred for many hours. This slowness in the progress of the effects from one system to another, constituted the peculiar advantage of employing this animal in the research, as, thereby, it was possible distinctly to determine the sequence of the phenomena. In animals of a higher type, the implication of one system so rapidly influences the others, that symptoms follow each other with such speed as to increase very greatly the difficulties of a clear apprehension.

The following are the conclusions of the investigation.

A. *Action through the Blood.*

1. Physostigma proved fatal to every animal hitherto examined, with the single exception of the Esĕrĕ moth. Death is most rapidly caused in birds and mammals by the injection of the poison into the circulation, or when it is brought in contact with a wounded surface. It follows nearly as quickly when Calabar bean is introduced into a serous cavity, and much less rapidly when introduced by the mucous membrane of the digestive system. In rabbits, death has been caused by its application to the Schneiderian, auditory, and conjunctival mucous membranes. The skin of frogs resists its effects for a long time, but, if applied for a sufficient period and with proper precautions, distinct evidence of its

absorption may be obtained, though death has never been caused by such application.

2. The contact of the extract of Calabar bean with the gastric juice of a dog for twenty-four hours, at a temperature a little above 95° F., did not, in the slightest degree, modify its energy.

3. A large dose, injected into the abdominal cavity of a frog, affects nearly simultaneously the heart and spinal cord,* and very rapidly destroys the vitality of both organs. With such a dose, the motor nerves are unaffected, and retain their conductivity for at least thirty hours. Evidence of the activity of the afferent nerves may be obtained so long as the retained vitality of the spinal cord permits of its diastaltic function being examined.

4. An average dose, in the first place, impairs the function of the spinal cord and diminishes the rate of the cardiac contractions and of the respiratory movements, and, soon after, these latter cease. In periods varying from one and a-half to four hours afterwards, *the motor nerves are paralysed*, this paralysis first implicating the endorgans of these nerves, and afterwards the nerve trunks. From this it must not be inferred that the nerve is paralysed by a centripetal progression of the poison, the only fact which was demonstrated being that a direct ratio existed between subdivision of nerve substance and facility of contact of poison, on the one hand, and, on the other, rapidity of paralysing effect. Indeed, division of the nerve trunk, previous to the administration of Calabar bean, delayed the paralysis of its endorgans. The afferent nerves retain their activity so long, at least, as the functions of the spinal cord are not lost, and this generally happens about the same time as the motor paralysis.

5. When a small but still fatal dose of Calabar bean is administered to a frog, the effects are the same as those in the previous conclusion, until they arrive at the stage of paralysis of the motor nerves, and, after this, an interval of several hours may elapse before the functions of the spinal cord are completely suspended. During this interval the *tactile* sensibility of the afferent nerves is increased; so that, if the ischiadic artery and vein of one limb were tied before the exhibition of the poison, an ordinary excitant, such

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* The effects on the spinal cord were determined by frequent measurements of the reflex activity by means of the Mètronome.

as sulphuric acid, will show everywhere a marked diminution, as measured by the metronome, in the diastaltic activity; while a slight touch of the skin in the poisoned region, which before the administration of the poison caused no effect, will now produce faint twitches of the limb whose vessels are tied.

6. *A frog may have its cardiac contractions reduced from seventy to eight or ten per minute, its respiratory movements completely stopped, and the endorgans of its motor nerves paralysed, by a still smaller dose, and afterwards completely recover.* This has occurred when two grains were injected into the abdominal cavity of a frog weighing seven hundred and thirty grains.

7. In frogs, the voluntary muscles are unaffected by the poison, and may continue to respond to galvanic stimulation during three or four days after its administration. The contrast and independence in the effects of Calabar bean on the motor nerves and on the muscles may be well shown by ligaturing the ischiadic vessels of one limb before injecting the poison. If, when strong stimulation causes no reflex movement, the two gastrocnemii muscles with their attached nerves are so placed that an interrupted current, from one Daniell's cell and Du Bois Reymond's induction apparatus, may be transmitted simultaneously, either through both muscles, or both nerve-trunks, it will be found, in the case of the muscles, that when the secondary coil is slowly advanced, contractions will occur with the same current in both muscles, or with a weaker current in the case of the poisoned than of the non-poisoned muscle, this varying with the length of time which has elapsed since the limb was deprived of blood; when the current is transmitted through both nerves, contractions will be simultaneously produced, or with a weaker current in the non-poisoned, or contractions will occur in the non-poisoned muscle only, this varying with the length of time which has elapsed since the exhibition of the poison.

8. In mammals and in birds the voluntary muscles are affected in a very remarkable manner. At an early stage of the poisoning faint twitches occur, which gradually extend over the body, and, at the same time, increase in vigour, so as to interfere with the respiratory movements. Shortly before death, they again become mere successive twitches, often requiring the hand to be placed

over the part in order to distinguish their existence. After death, if a muscular surface be exposed, these twitches will be observed to rarely involve the whole of one muscle, but at different times different muscular fasciculi; and they may persist for more than thirty minutes after death. They are caused by a direct effect of Calabar bean on the muscular substance. This is shown by their occurring in muscles after paralysis of the motor nerves, by their persisting in a muscle cut out of the body, and by their non-occurrence in parts which have been separated by ligature from the circulation.

9. The heart's action is rapidly slowered and then stopped, in birds and mammals, by a large dose. In dogs it may diminish to one-half in three minutes and cease in ten. A large dose injected into the abdominal cavity of a frog causes rapid and complete paralysis. A smaller dose causes either a gradual cessation and then a renewal at a diminished rate, or a gradual slowering from sixty or seventy to four or six beats per minute, followed by a gradual acceleration to a diminished rate varying from eight to twenty per minute. At this stage, and for many hours afterwards, the only signs of vitality are the diminished cardiac action and the power of the voluntary muscles to respond to galvanic and other stimulation. In the frog, where alone this diminution without stoppage, succeeded by partial acceleration, has been observed, the heart may continue so to contract for three, and for even five days, provided the temperature of the apartment be as low as 50° F. After stoppage, galvanic stimulation may cause a renewal of its rythmical contraction; but this is usually lost, and unrythmical and partial contractions can be only excited. The heart ceases to contract in diastole with all its chambers full.

10. The pneumogastric nerves retain their inhibitory power on the heart during the whole time from the diminution to the partial recovery of its action. Soon after this, however, they are paralysed; and this occurs at nearly the same time as the affection of the motor nerves.

11. Division of the pneumogastric nerves, or destruction of the medulla oblongata and medulla spinalis, does not protect the heart from the action of Physostigma.

12. The lymphatic hearts of frogs poisoned by Calabar bean soon cease to contract.

13. A large dose paralyses the cervical sympathetic nerves in rabbits before the death of the animal. A smaller fatal dose diminishes, without destroying, their activity.

14. Before the stoppage of the heart, proofs may be obtained of the vitality of its sympathetic ganglia, and, as striped muscle is not affected by Calabar bean conveyed by the blood, we are obliged to infer that the cardiac sympathetic system may be destroyed by a large dose, and its activity lessened by a smaller one.

15. The animal temperature, both external and internal, has been invariably observed to rise in rabbits and dogs, but only slightly.

16. The condition of the capillary circulation was examined in the web of the frog. Soon after the exhibition of the poison, the smaller arteries and veins contracted slightly; after a short interval, this contraction was succeeded by a rapid and permanent dilatation, in which the calibre of the vessels was considerably above their maximum previous to the poisoning. This dilatation of the capillaries appears to occur universally over the body, as is shown by a peculiar blue coloration of the voluntary muscles and of the heart, a similar coloration of the serous and fibro-serous tissues, and a congestion of the blood-vessels in the conjunctiva and iris. These changes occur, also, in a less marked manner, in birds and mammals.

17. The general results of experiments in which the arterial and venous tensions were examined were, that almost immediately after the administration of Calabar bean the arterial tension rose slightly, attained its maximum when the number of cardiac contractions had diminished to at least one-half, and then rapidly fell; and that the venous tension rose less quickly, attained its maximum when the arterial tension had diminished considerably, and, in its turn, fell, though more gradually than that of the arterial system. The number of the cardiac contractions, when the venous tension had attained its maximum, was about one-third of the average before the poisoning; the respirations were rather less frequent than before, and the temperature had risen a few tenths of a degree.

18. Physostigma causes extreme diffusion in the pigment cells of the frog's skin, and so a very marked change occurs in the colour of the animal during the progress of the symptoms.

19. The peristaltic action of the intestines is usually destroyed at death; it may, however, continue a short time afterwards.

20. The pupil contracts in all cases of rapid poisoning in mammalia and in birds. When the dose is small, in place of contraction, dilatation is sometimes observed; but this is extremely rare. In frogs the pupil has been generally observed to contract, but no connection could be determined between the dose and this symptom.

21. Calabar bean acts as an excitant of the secretory system, increasing the action of the alimentary mucous, of the lachrymal, and of the salivary glands.

22. The symptoms of poisoning are not materially altered, in the frog, by the removal of the brain or by division of the cervical portion of the spinal cord.

23. Artificial respiration does not prevent death in mammals after the exhibition of a poisonous dose. This is a necessary result of the effects of Physostigma on both the cerebro-spinal and sympathetic systems.

24. Congestion of internal organs occasionally occurs, but this is by no means an invariable consequence of a fatal dose.

25. The blood is dark after death, but becomes arterialised on exposure to the air; it usually clots loosely and imperfectly; and, when examined with the spectroscope, the bands of scarlet crurine are found unchanged. A microscopic examination demonstrates, in the rabbit and dog, an invariable change in the coloured corpuscles, which have their outlines distinctly crenated. This change is not observed in the blood of birds or amphibia. The white corpuscles remain unaltered.

B. *Topical Effects.*

1. When applied to the surface of the brain of a frog, no effect was produced; but when the poison was brought in contact with the spinal cord, a few twitches occurred in the extremities, followed by paralysis of the portion of cord acted on.

2. When Calabar bean is applied to a mixed nerve, in a concentrated form and with proper precautions to prevent absorption, the afferent nerve-fibres are first paralysed, and afterwards the efferent. This is readily demonstrated by acting on the sciatic nerve of the frog and, after some time, administering a small dose of strychnia.

3. Topical application destroys the contractility of striped and of unstriped muscular fibre. The heart's action is stopped by repeated application to the pericardium or to its external surface. If a sufficient quantity be injected into one of its chambers, paralysis nearly immediately follows.

4. The effects of the application of Calabar bean to the eyeball are a somewhat painful sensation of tension in the ciliary region, contraction of the pupil, with immobility in extreme contraction, myopia and astigmatism, congestion of the conjunctival vessels, and twitches of the orbicularis palpebrarum muscle.

3. On some Phenomena of Indistinct Vision. By Edward Sang, Esq.

If an exceedingly small luminous object be placed in front of the eye, but out of the range of distinct vision, it appears to be a roundish bright disc traversed by various markings, and most of these markings are found to be permanent for the same eye, but different for the two eyes. The subject of the present paper is a modification of this appearance.

Instead of a luminous point let us take a very narrow luminous line, such as a small slit in the window-shutter, or the reflection of the light of a fire from a polished metallic rod, and let us put this out of focus by means of a pair of convex spectacles. On regarding the luminous line, without any attempt to adjust the eye to distinct vision, we perceive a long luminous band, the breadth of which varies with the distance of the line. When the luminous line is brought into focus, the apparent breadth becomes zero; it increases as the line is moved beyond or within the distance for distinct vision.

If, having removed the shining line to a considerable distance, so as to obtain a pretty broad band, we take a thin ring, such as that used for keys, in the hand, and pass it close to the eye so as to intercept part of the light, we shall perceive that the bright band is traversed for its whole length by a dark line, and that this line moves across it in the direction of the motion of the ring.

On removing the ring to a little distance, the black line produced by it is seen to be curved in the same direction with the curvature of the ring; and an attentive examination shows that its curvature is much less than that belonging to the projection of the ring to the same distance. As the curved wire is farther removed, the appearance of the dark line becomes that of an elliptic arc taken from near the end of its shorter axis; and when the ring is taken to the distance proper for distinct vision, the dark band becomes circular, becomes, in fact, the true image of the ring itself.

If we continue to remove the ring to a greater distance from the eye, the curvature of the dark band is increased, and presents the appearance of a portion of an ellipse taken from near the end of the major axis. Its motion across the luminous band is evidently greater than that due to the movement of the ring.

Let us now bring the luminous slit within the distance for distinct vision, or, better, let us remove the optical focus to beyond the luminous slit, by wearing a pair of deep concave glasses, and we shall find that the motion of the dark line is opposite in direction to that of the ring, and that the curvature is also turned the other way.

It was this reversion which drew my attention to the phenomena; and, not recollecting of having seen it noticed, I thought it worth while to bring it before the Royal Society.

4. Note on Determinants of the Third Order. By Professor Tait.

Hamilton long ago showed that if we have

$$\begin{aligned} \alpha &= ix + jy + kz, \\ \beta &= ix_1 + jy_1 + kz_1, \\ \gamma &= ix_2 + jy_2 + kz_2, \end{aligned}$$

then

$$\mathrm{S}\,.\,\alpha\beta\gamma = - \begin{vmatrix} x & y & z \\ x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \end{vmatrix}$$

This opens up an exceedingly simple quaternion path to the proof of various properties of determinants of the third order. Several of those I subjoin have long been known, some, however, appear to be new, and our methods indicate how to obtain an unlimited number of new ones; but *all* are proved much more simply than by the usual processes.

(1.) We have at once, by quaternions,

$$S \,.\, (\alpha+\beta)(\beta+\gamma)(\gamma+\alpha) = 2\, S \,.\, \alpha\beta\gamma \,.$$

In its algebraic form this is

$$\begin{vmatrix} x+x_1 & y+y_1 & z+z_1 \\ x_1+x_2 & y_1+y_2 & z_1+z_2 \\ x_2+x & y_2+y & z_2+z \end{vmatrix} = 2 \begin{vmatrix} x & y & z \\ x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \end{vmatrix}$$

(2.) Again

$$S \,.\, V\alpha\beta \; V\beta\gamma \; V\gamma\alpha = -\, (S \,.\, \alpha\beta\gamma)^2,$$

or

$$\begin{vmatrix} yz_1 - zy_1 & zx_1 - xz_1 & xy_1 - yx_1 \\ y_1z_2 - z_1y_2 & z_1x_2 - x_1z_2 & x_1y_2 - y_1x_2 \\ y_2z - z_2y & z_2x - x_2z & x_2y - y_2x \end{vmatrix} = \begin{vmatrix} x & y & z \\ x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \end{vmatrix}^2$$

This is the well-known property of the *Reciprocal*, or determinant formed from the minors of the original determinant.

(3.) Since we have

$$V\alpha\beta = i \begin{vmatrix} y & z \\ y_1 & z_1 \end{vmatrix} + j \begin{vmatrix} z & x \\ z_1 & x_1 \end{vmatrix} + k \begin{vmatrix} x & y \\ x_1 & y_1 \end{vmatrix}$$

(whose application to (2) is obvious), we may also write

$$V\alpha\beta = \begin{vmatrix} i & & k \\ x & y & z \\ x_1 & y_1 & z_1 \end{vmatrix} .$$

(4.) But, if we put

$$\Delta = \begin{vmatrix} x & y & z \\ x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \end{vmatrix}$$

we have

$$V\alpha\beta = \left(i\frac{d}{dx_2} + j\frac{d}{dy_2} + k\frac{d}{dz_2} \right) \Delta$$

which is easily seen to agree with (3). From this many well-known theorems may be deduced at once.

(5.) By (1) and (2) we have

$$S\,.\,(V\alpha\beta + V\beta\gamma)\,(V\beta\gamma + V\gamma\alpha)\,(V\gamma\alpha + V\alpha\beta)$$
$$= 2\,S\,.\,V\alpha\beta\,V\beta\gamma\,V\gamma\alpha = -\,2\,(S\,.\,\alpha\beta\gamma)^2.$$

(6.) Similarly, if we put

$$\delta = V(\overline{V\alpha\beta + V\beta\gamma}\ \overline{V\beta\gamma + V\gamma\alpha}),\ \epsilon = V(\overline{V\beta\gamma + V\gamma\alpha}\ \overline{V\gamma\alpha + V\alpha\beta}),$$
$$\zeta = V\,(\overline{V\gamma\alpha + V\alpha\beta}\ \overline{V\alpha\beta + V\beta\gamma}),$$

we have

$$S\,.\,\delta\epsilon\zeta = -\,(S\,.\,\overline{V\alpha\beta + V\beta\gamma}\ \overline{V\beta\gamma + V\gamma\alpha}\ \overline{V\gamma\alpha + V\alpha\beta})^2$$
$$= -\,4\,(S\,.\,\alpha\beta\gamma)^4.$$

Such theorems may be multiplied indefinitely; but we have already reached a stage in which the algebraic form is very unwieldy.

(7.) The common rule for the multiplication of two determinants is, of course, easily found by this process in the form

$$S\,.\,\alpha\beta\gamma\,S\,.\,\alpha\beta_1\gamma_1 = \begin{vmatrix} S\alpha\alpha_1 & S\alpha\beta_1 & S\alpha\gamma_1 \\ S\beta\alpha_1 & S\beta\beta_1 & S\beta\gamma_1 \\ S\gamma\alpha_1 & S\gamma\beta_1 & S\gamma\gamma_1 \end{vmatrix}.$$

The following Gentlemen were admitted Fellows of the Society:—

T. B. Johnston, Esq.
George F. Barbour, Esq., of Bonskeid.
David Davidson, Esq.
Peter Waddell, Esq.
George Harvey, Esq.
George Stirling Home Drummond, Esq. of Ardoch.
Professor Fuller, Aberdeen.

The following Donations to the Library were announced:—

Transactions of the Royal Scottish Society of Arts. Vol. VII. Part 2. Edinburgh, 1866. 8vo.—*From the Society.*

Thirty-Ninth Annual Report of the Royal Scottish Academy of Painting, Sculpture, and Architecture. Edinburgh, 1866. 8vo.—*From the Academy.*

Journal of the Statistical Society of London. Vol. XXIX. Part 4. London, 1866. 8vo.—*From the Society.*

The American Journal of Science and Arts. Second Series. No. 126. New Haven, 1866. 8vo.—*From the Editors.*

Conferences Agricoles faites au champ d'experiences de Vincennes dans la saison de 1864. Par M. Georges Ville. Première—Sixième Conférence. Paris, 1865–66. 8vo.—*From the Author.*

Jahresbericht über die Fortschritte der Chemie und verwandter Theile anderen Wissenschaften. Unter Mitwirkung von C. Bohn und Th. Engelbach herausgegeben von Heinrich Will; für 1865. Zweites Heft. Giessen 1866. 8vo.—*From the Editors.*

Monatsbericht der Königlichen Preussischen Akademie der Wissenschaften zu Berlin. August 1866. 8vo.—*From the Academy.*

Annales des Mines. 6^e Série. Tome IX. 2^e, 3^e Livraison de 1866. Paris, 1866. 8vo.—*From the Commission of Mines.*

Résumé Météorologique de l'Année 1865, pour Genève et le Grand Saint-Bernard. Par E. Plantamour. Genève, 1866. 8vo.—*From the Author.*

Mémoires de la Société de Physique et d'Histoire Naturelle de Genève. Tome XVIII. 2 partie. 4to.—*From the Society.*

Expériences faites a Genève avec le pendule a Réversion. Par E. Plantamour. Genève, 1866. 4to.—*From the Author.*

Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen. XII. Band. Göttingen, 1866. 4to.—*From the Society.*

Almanaque Nautico para el año 1868, calculado de órden de S. M. en el observatorio de Marina de la Ciudad de S. Fernando. Cadiz, 1866. 8vo.—*From the Observatory.*

Monday, 7th January 1867.

THE HON. LORD NEAVES, Vice-President, in the Chair.

Dr **Hughes Bennett**, at the request of the Council, performed several experiments with a view of showing how, in modern times, physiology was successfully investigated by means of newly invented instruments. He noticed especially the subject of animal electricity, stating, that a specimen of the *Melapterurus beninensis* which had been forwarded to him from Old Calabar in Africa, had been preserved for eighteen months in one of the hot-houses of the Botanic Garden of this city. Unfortunately, it died only that afternoon. He regretted that the arrangements he had made for showing the electrical currents in muscles and nerves had failed, in consequence of the injury which had been inflicted on two of the delicate galvanometers, recently invented by Sir W. Thomson, in their transit from the University to the Society's Rooms. He proceeded, however, to show the influence of continued and interrupted streams of electricity, on muscles and nerves. The law of contraction in muscles, as determined by Pfluger, was clearly demonstrated, and the variations in the influence of the continued stream, according to its amount and direction, were fully exhibited. The phenomena of electrotonus and the excitability of nerves were next illustrated by experiments. He then explained and performed the experiment of Helmholz, demonstrating how the time which the nervous influence occupied in traversing a given distance of nerve might be determined with exactitude, and noticed the more recent experiments of Schelzke, and De Jaeger, as to the rapidity with which volition and sensation were produced. Lastly, he alluded to the action of recently invented Sphygmographs, Cardiographs, and the Kymographion, dwelling more particularly on the Sphygmosphone. This instrument enabled the time and rapidity of the pulse and movements of the heart to be accurately determined by the ear, in consequence of an arrangement which caused each pulsation to break a continued electrical circuit, that in its turn communicated a movement to levers which struck bells. The two halves of this Sphygmosphone might be removed to any distance, so that if connected with a telegraphic wire, the rhythm of the pulse of an individual in London might be made audible in Edinburgh.

Monday, 21st January 1867.

DR CHRISTISON, Vice-President, in the Chair.

The following Communications were read:—

1. On the Colours of the Soap-Bubble. By Sir David Brewster, K.H., F.R.S.

The colours of the soap-bubble have been the subject of frequent observation since the time of Boyle, Hook, and Newton, and they have been invariably ascribed "not to any colour in the medium itself in which they are formed, or on whose surfaces they appear, but solely to its greater or less thickness." The author of this paper had been led to doubt the correctness of this opinion, and while repeating the beautiful experiments of Professor Plateau "On the equilibrium of liquid films," he was led to discover the true cause of these colours, whether they are observed on the soap-bubble or on plane, convex, and concave films stretched across the mouths of closed or open vessels.

The paper, which is illustrated with numerous coloured drawings, is divided into five parts.

1. On the phenomena of colour in a vertical plane film.
2. On the production of revolving systems of coloured rings on the soap film.
3. On the form and movements of the bands and rings on convex and concave films.
4. On the phenomena produced by different solutions.
5. On the origin and development of the colours on the soap-bubble.

In these sections the author has shown that the colouring matter of the soap-bubble is secreted from the soap solution when reduced to the state of a film;—that it rises to the highest point of the film in colourless portions, in the form of a tadpole, which pass into molecules of every possible order of colour, and then take their proper place in the coloured bands;—that these bands move over the surface of the film under the influence of gravity, and may be blown into fragments or into molecules of all colours, or even recombined with the film; that they may be blown into two systems of coloured rings, the one revolving from right to left, and the other from left to right; and that under the influence of the centrifugal force, these molecules are carried into their place in Newton's scale—those of the first orders going to the centre of the rings, and followed by those of higher orders that happen to be in the film when it is blown upon through a tube in the direction of a diameter.

"It is impossible," the author adds, "to convey in language an adequate idea of the molecular movements, and the brilliant chromatic phenomena exhibited on the soap films, and it is equally impossible for art to delineate them. The visible secretion of a colourless fluid from a film less than the twelve thousandth of an inch in thickness,—its separation into portions of every possible colour,—the quick passage of these portions into bands of the different orders in Newton's scale,—their ever varying forms and hues when the bands either break up spontaneously, or are forcibly broken up,—their conversion into revolving systems of coloured rings under the influence of a centrifugal force,—their various motions when the film is at rest, and protected from aerial currents,—their recombination into a colourless fluid when driven to the centre or margin of concave and convex films, and their reabsorption by the film by means of mechanical diffusion, are facts constituting a system of visible molecular actions, of which we have no example, and nothing even approaching to it in Physics."

2. On the *Musculus Sternalis*. By William Turner, M.B., Demonstrator of Anatomy.

In this paper the author described the results of his observations on the presence of the musculus sternalis in upwards of six hundred bodies dissected in the anatomical rooms of the University of Edinburgh. He had found it in nineteen individuals, *i.e.*, in about 3 per cent. of the bodies examined. It occurred nearly equally in the two sexes. It bore no relation to the general muscularity of the individual. In eleven subjects the muscle was single, in eight double, making together twenty-seven specimens of the muscle. The variations which it exhibited in its attachments, size, and shape, were then described. In no case were its fibres continuous with those of the rectus abdominis, or were tendinous intersections found in it, but it mostly arose either from the flattened tendon of the external oblique muscle of the abdomen, or from the cartilages of the lower true ribs, and in many instances it was continuous at its upper end with the sternal tendon of one or both sterno-mastoids, whilst in others it was inserted into the aponeurosis covering the pectoralis major. It was always superficial to the great pectoral muscle. Of the single specimens, four occurred on the right side, two on the left; whilst in the remaining five it arose on one side of the middle line, and was inserted either altogether or in part on the opposite side. It formed an excellent illustration of the truth of the general statement, that occasional and rudimentary structures are especially liable to variations in arrangement.

A sketch of the history of the muscle, from the first observation by Cabrolius in 1604, was then given, and the various opinions as to its morphology were discussed. In opposition to the view usually entertained by anatomists, the author contended that it was not an upward extension of the rectus abdominis, such as is so frequently seen in the mammalia, so that the name rectus sternalis, or sternalis brutorum, usually applied to it, is not appropriate. For it was not continuous with the rectus, and was placed superficial to the pectoralis, whilst the anterior end of the mammalian rectus is always continuous with its abdominal part, and, moreover, concealed by the pectoral muscle; and further, another muscle has occasionally been seen in man which, differing in its position from the sternalis, lying under cover of the great pectoral muscle next the ribs, is undoubtedly to be regarded as homologous with the anterior end of the mammalian rectus.

The sternalis muscle, from many of its relations, seems to be most closely allied to the *panniculus carnosus*, or great skin muscle of the quadruped, and may perhaps be regarded as an additional rudiment of that muscle, occasionally present in man, though it must be admitted that the human platysma (which is generally acknowledged to represent the panniculus) lies on a plane superficial to the fibres of the sternalis in those individuals in whom they coexist.

3. On Compensation Pendulums of two Pieces. By Edward Sang, Esq.

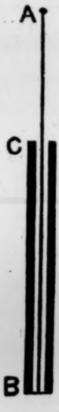
Three or four years ago, wishing to make some experiments on time-keepers, and desiring for that purpose to have a compensation pendulum fitted to my clock, I turned my attention to pendulums composed of two pieces, having different rates of expansion.

Such compensation pendulums are now pretty common; the idea which has led to their construction being this,—that if the pendulum rod be made of material having a very small rate of expansion, and if the bob or weight be of a substance much more expansive, then the upward expansion of the one may be made to compensate for the downward expansion of the other, and so the going of the clock may remain unaffected by changes of temperature.

On designing the arrangement, and on proceeding to make the calculation, according to the received expansions of deal and lead, I was much surprised to find the solution of the resulting equation to be impossible; and the surprise was the greater, because I had understood that of clocks constructed with such pendulums, the compensation had been verified by actual observations. There is not sufficient disparity between the expansibilities of deal and lead.

A very slight glance at the subject is sufficient to show, that if it be impossible to construct such a pendulum with a deal rod of great tenuity, and with an enclosing cylinder of lead also of inappreciable diameter, it must be impossible to make one with the parts having appreciable diameters; since the lateral expansion of the parts tends to augment the length of the corresponding simple pendulum.

Fig. 1.



Let us then suppose an exceedingly thin rod AB, of some slightly expansive substance, suspended by the end A, and having on the lower end B a small projection or seat, on which the end of a cylinder BC of heavy and expansive metal rests. Then neglecting the weight of the inner rod, and the radius of the cylinder, and putting AB $= b$, AC $= c$, and l for the length of the corresponding simple pendulum, we have

$$\frac{3}{2} l = \frac{b^2 + bc + c^2}{b + c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1.)$$

Let now β be the rate of expansion of the supporting rod AB, γ that of the cylinder BC, we have for a change of temperature t.

$$b' = b(1 + \beta t), \quad c' = c(1 + \gamma t).$$

and therefore, in order that there be no change in the value of b, we must have

$$\frac{b^2 + bc + c^2}{b + c} = \frac{3}{2} l = \frac{b'^2 + b'c' + c'^2}{b' + c'} = \frac{(3b^2 + 3bc)\beta + (2c^2 - bc - b^2)\gamma}{2b\beta - b\gamma + c\gamma}$$

whence the equation

$$\beta \,.\, b^3 + (4\beta - 2\gamma)b^2 c + (\beta + \gamma)bc^2 + \gamma c^3 = 0, \quad . \quad . \quad . \qquad (2.)$$

by help of which the ratio of b to c may be found. Now, unless γ exceed the double of β, all the terms of this equation have the same sign, and therefore there can be no positive root; so that, on this account, there can be no such pendulum as we are thinking of, unless the one rate of expansion be more than double of the other. In order to discover the least possible disparity of expansion, let us put $b = cx$, $\gamma = n\beta$, and our equation becomes

$$x^3 + (4 - 2n)x^2 + (1 + n)x + n = 0, \quad . \quad . \quad . \quad . \qquad (3.)$$

When our solution just begins to be possible, this equation must have two equal roots, and therefore must have a divisor common to it and its derivative

$$3x^3 + (8 - 4n)x^2 + (1 + n) = 0, \quad . \quad . \quad . \quad . \quad . \qquad (4.)$$

On eliminating x from the equations (3) and (4), we obtain an equation of the fifth degree; of which $n = 2$ is one solution, and on dividing there results the biquadratic

$$12n^4 - 80n^3 + 123n^2 - 60n + 4 = 0, \quad . \quad . \quad . \quad . \quad . \qquad (5.)$$

which has two possible roots, viz.,

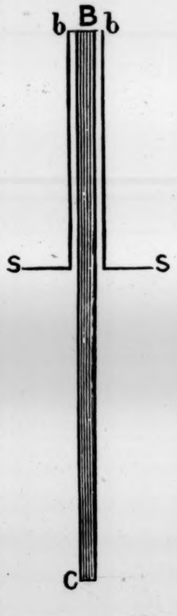
$$n = 0\,.\,07873 \ 06113 \ 75,$$

and $$n = 4\,.\,71418 \ 14416 \ 13.$$

The first of these can have no application to our present problem and the second, almost exactly $4\frac{5}{7}$, exceeds the ratio of the expansions of any two available solid substances. Thus we conclude that pendulums constructed of two pieces after the manner shown in figure 1, cannot be compensated.

The equation of condition (3) being of an odd degree, must have always one root possible. It is true that this is merely a numerical possibility, which may or may not be represented by a mechanical arrangement; yet it may be worth while to examine into it. Now, when n is positive, the equation (3), must have one of its roots negative, and thus the point B, corresponding to that root, must be the above point of suspension.

Fig. 2.



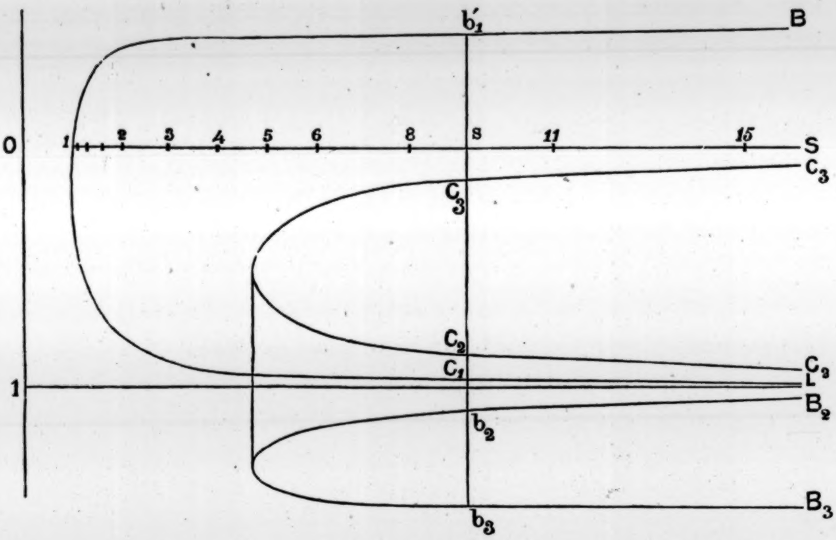
Let us suppose, then, a tube $abba$ of glass or some substance having a very slight expansion, to proceed upwards from the axis of motion SS, and from the upper end of the tube let a heavy rod, BC, of more expansive material depend, and the arrangement will represent, mechanically, the negative value of x obtained from the solution of the equation (3).

On assuming for n a number of successive values, and thence computing the corresponding roots of the equation (3), as also the values of a, b, and c, necessary to give a pendulum vibrating isochronously with a simple pendulum whose length is unit, and on representing the results geometrically, we obtain the diagram given in figure 3.

In this figure, the distances measured along the horizontal line OS indicate the ratio of the expansibilities of the two substances, OI standing for that of the suspender; Ol or SL is the length of the corresponding simple pendulum; and the curved lines marked B_1 B_2 B_3; C_1 C_2 C_3 define the values of b and c, corresponding to the three roots of the equation.

For example, if the ratios of the rates of expansion were 9 . 2, let us take the point s at that distance along OS, and draw through it a vertical line, crossing the six curves at the points b_1 c_3 c_2, c_1 b_2 b_3; then sb_1 c_1 shows the proportions for a pendulum constructed in the manner shown in figure 2. sb_2 c_2 shows that which is intended in the actual execution of clocks, while sb_3 c_3 is another possible arrangement of the same kind, and it is worthy of notice, that the

Fig. 3.



first of these three is always possible, although it be not desirable in practice.

The following Gentlemen were admitted Fellows of the Society:—

Andrew Graham, M.D., R.N.
William Turnbull, Esq.
A. H. Bryce, LL.D.
Francis Deas, LL.B.
Arthur Gamgee, M.D.
Sheriff Hallard.

The following Donations to the Society were announced:—

Proceedings of the Royal Society of London. Vol. XV. No. 88. 8vo.—*From the Society.*

Journal of the Royal Dublin Society. No. 35. 8vo.—*From the Society.*

Journal of the Royal Horticultural Society of London. Vol. I. Part 4. 8vo.—*From the Society.*

Proceedings of the same. Vol. I. (New Series). No. 6. 8vo.—*From the Society.*

Transactions of the Botanical Society of Edinburgh. Vol. VIII. Part 3. 8vo.—*From the Society.*

Journal of the Chemical Society. No. 49. London, 1867. 8vo.—*From the Society.*

Monthly Return of the Births, Deaths, and Marriages registered in the Eight principal Towns of Scotland. December 1866. 8vo.—*From the Registrar-General.*

An Essay to show that Petroleum may be used with advantage in Manufacturing Operations, for the purpose of heating Steam Boilers and generating Steam. By D. Bodde, Notary Public at Batavia. 8vo.—*From the Author.*

Bulletin de l'Académie Royale des Sciences, des Lettres, et des Beaux-Arts de Belgique. No. 12. Bruxelles, 1866. 8vo.—*From the Academy.*

Monatsberichte der Königlichen Preussischen Akademie der Wissenschaften zu Berlin, Sept.—Oct., 1866. 8vo.—*From the Academy.*

Die Menschlichen Parasiten und die von Ihnen Herrührenden Krankheiten. Ein Hand und Lehrbuch für Naturforscher und Aerzte. Von Rudolf Leuckart. Zweiter Band. I. Lieferung. Leipzig, 1867. 8vo.—*From the Editor.*

Comparisons of the Standards of Length of England, France, Belgium, Prussia, Russia, India, and Australia, made at the Ordnance Survey Office, Southampton. London, 1866. 4to.—*From the Survey.*

Sur la Vrille des Cucurbitacées. Par M. Ad. Chatin.—*From the Author.*

Monday, 4th February 1867.

Sir DAVID BREWSTER, President, in the Chair.

The following Communications were read:—

1. On the Tertiary Volcanic Rocks of the British Islands.

By Archibald Geikie, Esq., F.R.S.

This paper was in continuation of the series of memoirs on the volcanic rocks of Scotland previously read by the author before the Society,* and contained the first portion of the results of a survey of the western region, extending from the south of Antrim to the north of Syke. The districts more especially dwelt upon were the islands of Mull, Eigg, and Staffa. After alluding to the writings of previous geologists upon these tracts, more particularly to the discovery by the Duke of Argyll of tertiary leaves under basalt at Ardtun Head, in Mull, the author remarked that up to this time the great mass of volcanic rocks in the Western Islands has been usually regarded as of Oolitic age—an opinion in which he himself had shared. His object in the present communication was to show that as regards Mull and the adjoining islets this opinion was erroneous, that the enormous volcanic accumulations of these islands belonged in reality to the Miocene period, and that, in all likelihood, the long chain of basaltic masses, extending from the north of Ireland along the west coast of Scotland to the Faroe Islands, and beyond these to Iceland, was all erupted during the same wide interval in the Tertiary periods.

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* See Proceedings, iv. 309, 453, 582, and Transactions, vol. xxii. 633.

The nature of the volcanic products was first sketched. It was shown that the two great classes of recent lavas—the basaltic and the trachytic—were well represented among the Western Islands, and that the basaltic series was on the whole the older, since it was found to pass under massive sheets of pale grey and blue claystones, clinkstones, and porphyries belonging to the trachytic group. In addition to these lava-form rocks, masses of coarse volcanic agglomerate occurred, along with beds of tuff and peperino.

The manner in which these various volcanic rocks occur in Mull and Eigg was next described. It was shown that the leaf-beds of Ardtun, which are known by their fossil contents to be of Miocene age, lie near the bottom of the whole volcanic series, and that above them comes a series of trap-beds between 3000 and 4000 feet in thickness. Throughout this enormous mass of bedded igneous rock layers of ash, often abounding in chalk-flints, are interstratified, and in one part of the cliffs of Inimore of Carsaig a bed of flints twenty-five feet thick lies between the dolerites. Thin lenticular seams or nests of coal likewise occur, but these only occupy small pond-like hollows of the original surface of the trap beds, and are overlaid directly with trap. They are sometimes excellent in quality, and occasionally three feet in thickness; but they rapidly die out in every direction. There is thus no probability that the tertiary coal of the Western Islands will ever come to be of commercial importance.

Proofs of the long continuance of volcanic action among these islands are afforded by the great thickness of the successive sheets of igneous matter, which in one mountain alone—Ben More—reach a depth of 3185 feet without revealing either the actual bottom or top of the series. Another and striking piece of evidence on this subject is given by the well-known Scuir of Eigg. That island consists of nearly horizontal sheets of dolerite, like those of Mull, resting unconformably upon oolitic rocks. After their eruption, they must have been long exposed to the wasting agencies of the atmosphere. A valley was cut out of them, and its bottom was watered by a river, which brought down coarse shingle and sand from the distant Cambrian mountains of the north-west. These changes must have demanded a lengthened lapse of time, yet they took place during an interval in the volcanic history of the island. The igneous forces which had been long dormant broke out anew, and poured several successive *coulées* of vitreous lava down the river-bed. In this way the channel of the stream came to be sealed up. But the same powers of waste which had scooped out that channel continued their operation. The hills which had bounded the valley crumbled away, and the lava-currents that filled the river-bed being much harder than the surrounding rocks, were enabled in great measure to resist the degradation. Hence the singular result now appears that the former hills have been levelled down into slopes and valleys, while the ancient valley occupies the highest ground in the neighbourhood, and its lava-current stands up as the well-known precipitous ridge of the Scuir of Eigg. The gravel and drift-wood of the old river are still to be seen under the rock of the Scuir.

The author then proceeded to point out the possible connection between these tertiary volcanic rocks and the metamorphism of different parts of the West Highlands. He showed that in Mull, under Ben More, the volcanic rocks themselves give signs of having been subjected to a process of metamorphism, and that they are associated there with masses of syenite, like those of Raasay and Skye. Macculloch pointed out that the syenite of the two latter islands was later than the secondary rocks of that district;

and there now seems to be a strong probability that it will turn out to be of Miocene age. Parts of that syenite are true granite, while the lias around it has suffered an extensive metamorphism. It will be an important addition to our knowledge of the history of metamorphic action, if the alteration of the secondary rocks of the Hebrides is eventually shown to be connected with the evolution of volcanic rocks during the Miocene period.

The wide extent to which the British Islands were affected by the Miocene volcanoes of the west was then referred to. That extent is not to be measured by the area at present covered with tertiary volcanic rocks, nor even by the area which these rocks may have originally overspread, but from which subsequent denudation has removed them. From the great volcanic ridge running through Antrim and the Western Islands, thousands of trap-dykes diverge in a south-easterly direction. They become fewer as the distance from that bank increases, yet they extend as far as the coast of Yorkshire. No single dyke, indeed, has been traced across the country from sea to sea, but there can be little doubt that they all belong to one series. They cut through all the formations up to and including the chalk, and they likewise traverse the older portions of the tertiary volcanic rocks. They must thus be of tertiary age, and belong to that series of igneous masses described in the present paper. They do not usually run along lines of fault; on the contrary, they are found to cross faults of fifty fathoms and upwards without being deflected. Their evenness and parallelism show that they must have ascended through fissures prepared for them by subterranean movements. Thus we learn that in tertiary times the greater part of Scotland, the north of England, and the north of Ireland, were cracked by earthquakes, and that liquid lava rose through the hundreds of parallel rents, perhaps in some cases actually reaching the surface.

The last section of the paper was devoted to an account of the denudation of the tertiary volcanic rocks. It was shown that wide, deep, and long valleys have been excavated out of the horizontal trap-beds; that these rocks have sometimes been so wasted away that only huge detached pyramids of them are left, as in the case of Ben More, Mull; that the volcanic bank has been worn down into detached islands often miles apart; and that from the fact of so many trap-dyes reaching the surface, even at a distance of more than 200 miles from the main mass of volcanic rock, the general superficies of the country must have undergone a very extensive amount of denudation since the Miocene period. These changes point to the passing of an enormous lapse of time, and help to teach us that, though in a geological sense the Miocene ages belonged to a recent part of the earth's history, they are yet separated from our own period by an interval too vast to be realised by the mind.

2. Note on the Action of Ammonia on Dicloracetone. By Dr A. Crum Brown.

For some time I have been engaged in an attempt to replace the chlorine in monochloracetone and dichloracetone by other radicals, and with this object have acted upon them by means of cyanide of potassium, acetate of soda, and aqueous and alcoholic ammonia. In all of these cases the chlorine was removed as chloride of the alkaline metal or ammonium, and brown, tarry substances were produced, which resisted all attempts at purification. By the action of dry ammonia gas, however, I have obtained somewhat better results.

When anhydrous dichloracetone, kept cold by means of a freezing mixture, is saturated with dry ammonia, white acicular crystals are gradually deposited, and these increase in quantity until the whole is converted into a white solid mass. If the substances have been kept below 0° C., nothing can be seen but these crystals. I have not yet been able to analyse them, on account of the great rapidity with which they decompose at higher temperatures. If the vessel in which they have been deposited be removed from the freezing mixture and exposed to the temperature of the room (in one case, not above 10° C.), they quickly disappear, and we obtain a yellowish liquid, and a copious crystallisation of chloride of ammonium. The liquid contains some unchanged dichloracetone, and a viscous substance which has a peculiar odour, resembling that of acetamide. This substance appears to be colourless when pure; it is only faintly yellow when it has not been exposed to heat, but a very slight warmth colours it brown.

The acicular crystals dissolve readily and completely in ether and in alcohol; these solutions also rapidly decompose, chloride of ammonium being deposited, and the viscous substance above mentioned remaining in solution.

It would be premature to speculate on the nature of these substances without quantitative analyses; I hope before long to be able to lay these before the Society.

3. On the Figures of Equilibrium of Liquid Films. By Sir David Brewster, K.H., F.R.S.

In repeating some of the experiments of Professor Plateau, described in seven interesting memoirs published in "The Transactions of the Belgian Academy," and in prosecuting his own experiments on the colours of the soap-bubble, the author of this paper observed several new phenomena which may have escaped the notice of the Belgian philosopher.

Professor Plateau has described and drawn the beautiful systems of soap-films, obtained by lifting from a soap solution a cube made of wires about one and a half inch long. This system is a polyhedron, composed of twelve similar films stretching from the wires, and united to a plane quadrangular film in the centre. When this vertical film was blown upon, M. Von Rees observed that it was reduced to a line, and then reproduced in a horizontal position, from which it could be blown again into a vertical position.

If we suppose the quadrangular film removed, and all the twelve films radiating from the centre of the cube, Professor Plateau found that such a system could not be kept in equilibrium, unless there was something solid in the central point, such as the end of a wire or a drop of fluid.

In repeating these experiments the author found that, after converting the horizontal into the vertical quadrangular film, and continuing the blowing, he produced the radial system of films, which in an instant returned to the system with a vertical film, and then into the system with the horizontal film.

M. Von Rees had found that, by immersing the wire cube with the normal polyhedron a few millimetres in the soap solution, the film formed on its lower face imprisoned the air in the quadrangular pyramid above it, and that this air rose to the centre of the cube, and replaced the quadrangular plane with a hollow cube with curved faces.

In this beautiful experiment the hollow cube is invariable in size, being necessarily equal in its contents to one-fourth part of the wire cube. The author of the present paper discovered a method of inserting a hollow cube of any magnitude in the centre of the polyhedron. This was done by blowing a bubble of the requisite size, and introducing it within the wire cube. He succeeded also by this means in inserting a second hollow cube beside the first, the side common to both being plane when the two cubes were equal, convex when the one was less, and concave when it was greater than the other. In such a system, which is in perfect equilibrium, the number of films is *nineteen.* He found also that two hollow solid figures could, by the same means, be inserted in the other systems of films which Professor Plateau had discovered in a wire tetrahedron, or a quadrangular pyramid, or a regular octohedron, or a rectangular prism, or in a system obtained from two rectangular planes fixed at right angles to each other.

This last and interesting system consists of four curved films extending from each vertical wire, and connected with an elliptical film in the common section of the rectangles. The major axis of this film is four times greater than its minor axis, and it is placed in the angle, which is a little greater than 90°, but sometimes also in the other angle.

By making this system of wires movable, so that the rectangular planes can pass from 90° to 180°, the author obtained some singular results. As the angle increased from 90°, the minor axis of the elliptical film increased, till when it approached to 180° it was nearly circular, appropriating gradually the fluid of the four curved films attached to the wires.

By again diminishing this angle the almost circular film became more and more elliptical, till it reached its normal state at 90°, giving back to the curved films the fluid which formed them. If the angle of the rectangular plane which contain the elliptical film is diminished, the film will grow more elliptical, and at 45°

will become a straight line, giving up its fluid to the other four films. At this instant the whole system changes, the oval film being reproduced in the angle of 135°!

Remarkable as this phenomenon is, there is one still more remarkable, which requires the testimony of the eye to make it credible. If when the rectangles are inclined 90° we blow upon the elliptical film, a bubble of such a size as to replace the system of films with a hollow curvilineal cube, and wait till it bursts, *the system of liquid films which it expelled will reappear, as if it had left its ghost behind it to recover the elements which the bubble had appropriated!*

By uniting the upper and lower ends of all the wires in this system, and also by uniting the wires at various points in their length, the author obtained a number of beautiful and complex systems of films, which require numerous diagrams to make them intelligible.

After treating of the equilibrium of liquid films, as seen in the union of spherical bubbles and other hollow solids, the author considers the formation of plane, convex, and concave films upon the mouths of open and closed vessels of different shapes, and their deposition on the same vessels from bubbles; and he describes various remarkable movements of the films, upwards and downwards, when they are formed upon conical vessels open at both ends.

4. On a Method of ascertaining the Specific Gravity of Water which holds a minute quantity of Foreign Matter in Solution; or, on the Specific Gravity of Impure Water.

By Edward Sang, Esq.

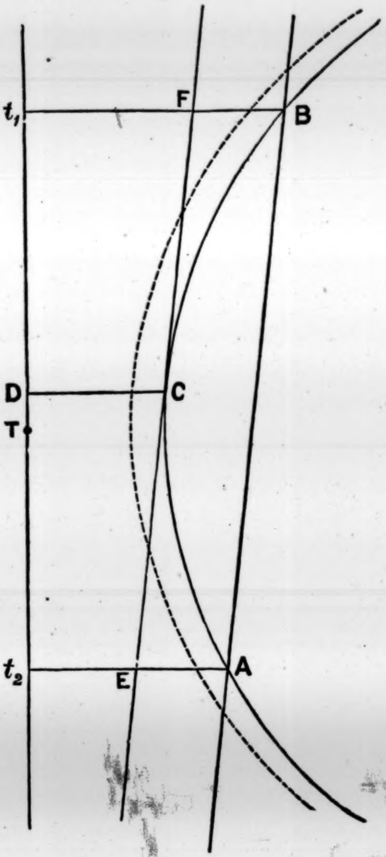
The determination of the degree of impurity of spring or well water is every day becoming of more and more importance. In order to discover how much foreign matter is contained in a sample of water, the chemist is under the necessity of drying up a quantity of it, and of weighing the residue. This operation is tedious, and gives a trust-worthy result only when the evaporation has been carried on in closed vessels from which atmospheric impurities have been carefully excluded; and, therefore, any assistance which can be obtained from mechanical measurements must be acceptable as affording a test for confirmation of the results.

If we attempt to find the specific gravity of any potable water by means of the balance, we encounter very great obstacles; the extreme delicacy of the weighing, and the uncertainty introduced by changes of temperature during the process, render the direct method almost valueless; since both the expansion of the water and that of the glass vessel in which it is contained would need to be allowed for. But, by taking advantage of the peculiarity of water in regard to changes of temperature, we can obtain an extremely sensitive indicator of changes in its composition.

Let us prepare a glass ball, adjusted in its specific gravity so that it will just float in pure water between the temperature of melting ice and 5 degrees of the centigrade thermometer (between 32° and 42° of Fahrenheit's), and placing a delicately graduated thermometer along with it in a jar of cold water, let the whole be allowed slowly to become warmer. The effect of an increase of temperature at first is to produce a contraction in the water, and at the same time a slight expansion in the glass of the ball; and the result is that, when the temperature becomes such that the two specific gravities are alike, the ball begins to float upwards. By placing the ball of the thermometer at some distance from the bottom of the vessel, we can note the temperature at the instant when the ball passes it; let this temperature be t_1.

As the water continues to grow warmer its density augments, but more and more slowly, until it reach its maximum; after this the water begins to expand, and eventually the glass ball, which had risen to the top, begins to descend. If we note the temperature t_2, at which the ball again passes the thermometer bulb, we shall have, in the difference $t_2 - t_1$ between the two temperatures, an argument by help of which to compute the relative densities of the water and the glass.

Since the expansion of water on either side of its state of maximum density is proportional to the square of the change of temperature from that point, if we were to measure, on the line of abscissæ, equal distances to represent the degrees of temperature, and were to lay off ordinates to represent the corresponding volumes of a given quantity of water, the line thus produced would be a parabola. Having traced the curve, let ordinates t_1 A and t_2 B be drawn corresponding to the observed temperatures t_1, t_2, and let the points A and B at which these cut the curve, be joined by a straight line A B. This line is not parallel to the line of abscissæ, but is inclined so as to show the rate of expansion of the glass ball, and a line drawn parallel to it to touch the curve will do so, not on the ordinate which shows the maximum density of the water, but on the ordinate mid-way between t_1 and t_2; which ordinate D C would indicate the temperature at which the water would seem to have the greatest density when inclosed in a thermometer tube made of the same kind of glass. The distance E A, or F B between the tangent and the chord is, according to the well-known properties of the parabola, proportional to the square of the intercepted absciss Dt_2, or to that of its double t_1 t_2.



Hence the square of the observed interval t_1 t_2 between the two temperatures at which the ball passes the thermometer bulb, when multiplied by some constant number to be determined by means of the known formula for the expansion of water, will give the difference between the glass and the water, when each is of the temperature half-way between t_1 and t_2.

If now we mix in the water some soluble salt, so as to change slightly its specific gravity, without perceptibly altering the law of its expansion, we shall thereby augment the interval between the temperatures at which the ball passes the thermometer; and the difference between the squares of the interval in the one case and in the other will be proportional to the change in the specific gravity of the water, which again, when the amount of impurity is minute, may be held as being proportional to the amount of that impurity.

The determination, by this method, of the quantity of heavy impurity in potable water may be freed from all dependence on a knowledge of the co-efficients of the expansibility of water, by comparing the observations made on distilled water with those made on water containing a known quantity of lime or other saline matter. And this, indeed, is the only useful method of procedure; for in the apparatus exhibited there are many glass balls, and, to distinguish these from each other, they are made of glass of various colours; and it is found that the means of the temperatures at which these pass the thermometer are different for the different colours. These means are also influenced by the conformation of the balls; thus those which are thin, and which, consequently, have heavy drops, are more acted on by the expansion of the internal air, than those are which have thick sides, and, consequently, small drops.

By using a glass ball adjusted to float in pure water just at its maximum relative density, we obtain the greatest delicacy in the indications. I found that such a ball, when placed in the water supplied to the New Town of Edinburgh, gave an interval of 17·2 degrees on Fahrenheit's thermometer. And the same method may be extended to the case of balls which float on water of much higher temperatures, only it then becomes necessary to use a thermometer of proportionally greater delicacy in its graduations. And it may be remarked that, for the purpose of securing certainty in the indications, it is expedient to inclose the jar containing the water to be experimented on in a large vessel also containing water, and to agitate the water contained in it so as to keep the fluid in the internal vessel as nearly as possible at the same temperature from top to bottom. By this arrangement we almost entirely avoid the formation of internal currents, which would tend to give uncertainty to the observations.

5. On the Oxidation of Phenyl Alcohol, and a Mechanical Arrangement adapted to illustrate Structure in the Non-saturated Hydrocarbons. By J. Dewar, Esq. Communicated by Professor Playfair.

The syntheses and oxidation analyses of organic compounds have so confirmed each other in many cases, that chemists are enabled to judge of the structure of a compound from the oxidation products. Many chemists have used the oxidation method in special cases, the bodies operated upon belonging principally to the fatty series; but until Fittig and Beilstein published their memoirs on the aromatic compounds, it was never applied to the systematic study of a hydrocarbon and its derivatives. But although the syntheses and oxidation analyses of the derivatives of benzol confirmed each other, still the structure of the original nucleus (benzol) remained unexplained. Kekulê's original and elegant speculations on the structure of benzol and its derivatives induced me to try the effect of oxidising agents on benzol, with the view of eliciting whether the carbon atoms would separate in the way theory pointed out. The carbon atoms in benzol may be supposed to be arranged in a closed chain, where the carbon affinities are bound two and one alternately. Now, if we examine the formula graphically, it is evident there are three symmetrical groupings, C_2H_2 (acetylene), in benzol. We would, therefore, expect the carbons to separate in twos, and produce the corresponding oxidised product, $C_2H_2O_4$, oxalic acid. I attempted the oxidation of benzol with permanganate of potash, but no decomposition took place in a sealed tube at 150° C. I then had recourse to phenyl alcohol. If a solution of permanganate of potash is added to phenyl alcohol, dissolved in water, the decomposition is immediate, the solution becomes alkaline, and peroxide of manganese separates as a bulky precipitate. Equivalent quantities of the substances, 1 pt. phenyl alcohol to 3·5 pts. of permanganate of potash were the proportions used. If the liquid is filtered and acidulated with acetic acid, on the addition of acetate of lime, a white precipitate of oxalate of lime separates. I have analysed the lime salt, and also examined the physical properties of the acid. So that phenyl alcohol, when treated with one-third of the quantity of permanganate of potash necessary for complete oxidation, gives oxalic acid. If the oxidising agent had been in excess, we could not have considered the action specific; but as Berthelot has shown that acetylene can be condensed into benzol, and that acetylene, when oxidised, gives oxalic acid, we must consider the production of oxalic acid as depending on the more intimate union of the two carbon atoms.

By the regulated oxidation of phenyl alcohol several substances must be produced. If we compare benzol and naphthalin, both members of a homologous series of hydrocarbons where the common difference is C_4H_2, we would expect them to undergo a similar decomposition on oxidation. And as naphthalin, when oxidised, gives oxalic and phthalic acids, thus

$$C_8H_6 . C_2H_2 + O_8 = C_8H_6O_4 + C_2H_2O_4,$$

so we would expect benzol to give oxalic and fumaric or an isomer, thus

$$C_4H_4 . C_2H_2 + O_8 = C_4H_4O_4 + C_2H_2O_4.$$

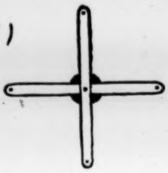
But if the resisting nucleus in benzol be C_4H_2, we would expect the formation of an acid, $C_4H_2O_4$ mellitic. So far as my experiments have gone, they prove the formation of two other acids along with oxalic, when two molecules of permanganate of potash to one of phenyl alcohol were used. When the alkaline liquid, after filtration from the manganic oxide, is strongly acidulated with hydrochloric acid, shaken up with ether, and the ethereal extract evaporated on the water-bath, a yellow resinous acid, giving a purple colour, with ferric chloride, is left. If this substance is heated, it chars, giving a beautiful sublimate in the form of long needles. The crystalline acid has a styptic taste, and gives a strong reddish violet reaction with ferric chloride, but no reaction with ferrous sulphate or lime water. The acid, therefore, differs from pyrogallic. Whether this crystalline acid is a decomposition product of the resinous acid, or the same substance separated from an impurity, further experiments must decide. When the acid liquid left, after separating the ether, is evaporated to dryness, treated with alcohol to dissolve the oxalic acid, freed from alcohol by evaporation, and the lime salt precipitated in presence of acetic acid, the percentage of lime, in the precipitate, was 4 per cent. below the theoretical quantity required for oxalate of lime. Analysis gave 34·1 per cent. of lime instead of 38·3 per cent.; the salt blackening on ignition. There must therefore be an acid along with oxalic whose lime salt is insoluble in acetic acid, and, judging from the percentage of lime, probably fumaric or mellitic. Further experiments on a larger scale must be made before the exact composition of the two acids can be affirmed.

The application of permanganate potash as an oxidising agent in organic chemistry promises interesting results. Many hydrocarbons are directly attacked, such as the oil from caoutchouc, some of the substances in Young's paraffin oil, &c., while others, having the same composition, resist. It may prove of great value in investigating the isomeric hydrocarbons.

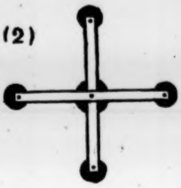
In connection with this subject, I bring before the Society a simple mechanical arrangement adapted to illustrate structure in the non-saturated hydrocarbons. This little device is the mechanical representative of Dr C. Brown's well-known graphic notation. A series of narrow thin bars of brass of equal length are taken, and every two of the bars clamped in the centre by a nut, so as to admit of free motion the one on the other. Such a combination represents a single carbon atom with its four places of attachment. In order to make the combination look like an atom, a thin round disc of blackened brass can be placed under the central nut. At the ends of the arms are holes to connect one carbon atom with another by means of a nut. The filling up of the places of attachment may be effected by slipping on the arms round discs of brass having a groove attached, and placing the symbol of the chemical element on the round projection. A carbon atom would then look like the following diagram (see p. 85).

As it is only intended to express the number of places of attachment along with the arrangement, when a given number of carbon atoms are combined in different ways, it is better to dispense with the symbols, remembering that every free arm represents a place of attachment. When a number of carbon atoms are joined together, all the joints and arms being moveable, it is easy to show saturation in a closed or open chain, and the many arrangements of the atoms corresponding to the same formula. Although the

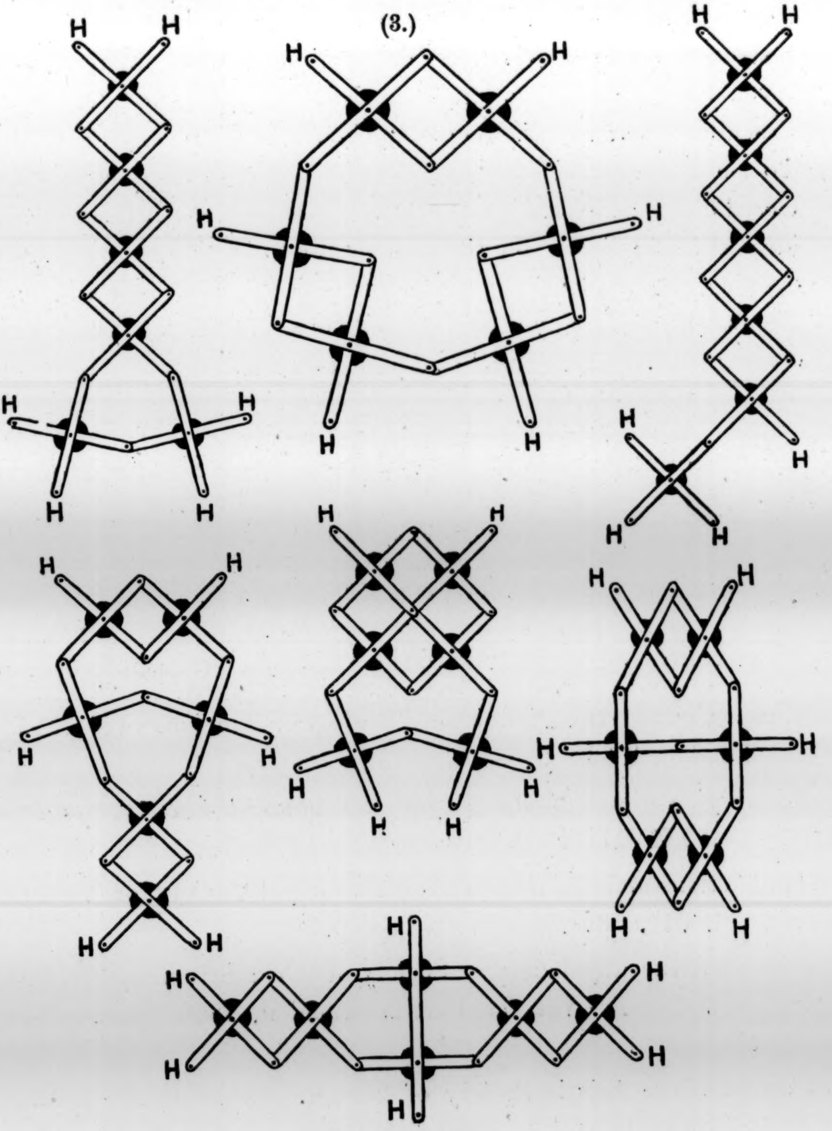
(1)



(2)



(3.)



Formulæ of Benzol.

bars are of equal length they are not intended to represent equal forces. We have no unit for comparing the values of the unit affinities in different atoms, and they may be incommensurable. In filling up the places of attachment we saturate the fixing powers of the individual atoms, taking no account of the influence the different elements and radicals have in affecting the energy of the whole compound. Without entering into any detail on the structure of the hydrocarbons, to show the ease with which the instrument can represent the same hydrocarbon in different ways, seven formulæ of benzol are appended. To show the latent affinities, all we have to do is to open the bars connecting any two atoms. To show the six latent affinities in benzol, as represented in a closed circuit, we have merely to separate the bars a little, when we have six free places on the outside, and six in the inside. By opening the whole arrangement we get fourteen free affinities. Naphthalin and many other hydrocarbons give elegant symmetrical diagrams when represented as a closed circuit.

The following Gentlemen were elected Members of the Society:—

Thomas R. Fraser, M.D.
Thomas Annandale, F.R.C.S.
D. R. Haldane, M.D., F.R.C.P.E.

The following Donations to the Library were announced:—

Transactions of the Pathological Society of London. Vol. XVII. London, 1866. 8vo.—*From the Society.*

Monthly Notices of the Royal Astronomical Society, London. Vol. XXVII. No. 2. 8vo.—*From the Society.*

Transactions and Proceedings of the Royal Society of Victoria. Vol. VII. 8vo.—*From the Society.*

Journal of the Royal Asiatic Society of Great Britain and Ireland. New Series. Vol. II. Part 2. London, 1866. 8vo.—*From the Society.*

Journal of the Asiatic Society of Bengal. Edited by the Natural History Secretary. Part 2, No. 2. Calcutta, 1866. 8vo.—*From the Society.*

Journal of the Asiatic Society of Bengal. Edited by the Philological Secretary. Part 1. No. 2. Calcutta, 1866. 8vo.—*From the Society.*

Sitzungsberichte der Königl.-bayer Akademie der Wissenschaften zu Munchen. Tome I. Heft 2, Tome II. Heft 1. Munchen, 1866. 8vo.—*From the Academy.*

Bulletin de la Société des Sciences Naturelles de Neuchatel. Tome VII. Neuchatel, 1866. 8vo.—*From the Society.*

Das Testament des Grossen Kurfürsten, von Joh. Gust. Droysen. Leipzig, 1866. 8vo.—*From the Royal Saxon Academy.*

Tables of Heights in North-west Provinces and Bengal, determined by the Great Trigonometrical Survey of India, by Spirit-levelling Operations, to May 1865. Roorkee, 1866. 8vo.—*From the Survey.*

Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig. Heft 1, 2, 3. 1866. 8vo.—*From the Society.*

Sul Monto Ondosa del Mare e su le Correnti di esso Specialmente su Quelle Littorali, pel Comm. Alessandro Cialdi. Rome, 1866. 8vo.—*From the Author.*

Les Ports-Canaux. Article Extrait de l'Ouvrage sur le Mouvement des Ondes sur les Courants Littoraux par le Comm. Alexandre Cialdi. Rome, 1866. 8vo.—*From the Author.*

Bulletin de la Société de Géographie, December 1866. Paris, 1866. 8vo.—*From the Society.*

Flora Batava, Afbeelding en beschrijving van Nederlandsche Gewassen. Door Wijlen Jan Kops, vervolgd door Jhr. F. A. Hartsen. No. 196–199. Amsterdam. 4to.—*From the Authors.*

Journal of the Linnean Society. Vol. IX. Zoology, No. 35. London, 1867. 8vo.—*From the Society.*

Journal of the Chemical Society. Series II. Vol. IV. No. 48. London, 1866. 8vo.—*From the Society.*

Bulletin de l'Académie Royale des Sciences, des Lettres, et des Beaux-Arts de Belgique. No. 1. 1867. Bruxelles, 1867. 8vo.—*From the Society.*

Cartes Géologique et Hydrologique de la Ville de Paris. Par M. Delesse. 8vo.—*From the Author.*

Recherches sur l'Origine des Roches. Par M. Delesse. Paris, 1865. 8vo.—*From the Author.*

Recherches sur l'Eau dans l'interieur de la Terre. Par M. Delesse. 8vo.—*From the Author.*